

Marine Fish and Invertebrate Atlas: Summarizing Geographic Distribution and Population Indices in the Scotian Shelf and Bay of Fundy (1970-2020)

Daniel Ricard and Catalina Gomez

Science Branch
Gulf Region
Fisheries and Oceans Canada
Moncton, New Brunswick, E1C 5K4, Canada

Science Branch
Maritimes Region
Fisheries and Oceans Canada
Dartmouth, Nova Scotia, B2Y 4A2, Canada

2021

**Canadian Technical Report of
Fisheries and Aquatic Sciences #####**



Fisheries and Oceans
Canada

Pêches et Océans
Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques*.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences nnn

2021

MARINE FISH AND INVERTEBRATE ATLAS: SUMMARIZING GEOGRAPHIC DISTRIBUTION,
POPULATION INDICES AND ENVIRONMENTAL PREFERENCES IN THE SCOTIAN SHELF
AND BAY OF FUNDY (1970-2020)

by

Daniel Ricard ¹ Catalina Gomez ²

¹Science Branch
Gulf Region
Fisheries and Oceans Canada
Moncton, New Brunswick, E1C 5K4, Canada
²Science Branch
Maritimes Region
Fisheries and Oceans Canada
Dartmouth, Nova Scotia, B2Y 4A2, Canada

© Her Majesty the Queen in Right of Canada, 2021
Cat. No. Fs97-6/nnnE-PDF ISBN ISSN 1488-5379

Correct citation for this publication:

Ricard, D. and Gomez, C. 2021. Marine Fish and Invertebrate Atlas: Summarizing Geographic Distribution, Population Indices and Environmental Preferences in the Scotian Shelf and Bay of Fundy (1970-2020). Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 17 p.

CONTENTS

ABSTRACT	iv
RÉSUMÉ	v
1 Introduction	1
2 Methods	2
2.1 Survey Description	2
2.2 Sampling Design	3
2.3 Taxonomic Levels	4
2.4 Analyses	13
2.4.1 Geographic distribution of catches	13
2.4.2 Abundance and biomass indices	13
2.4.3 Distribution indices	13
2.4.4 Length frequencies	13
2.4.5 Length-weight relationship and condition factor	14
2.4.6 Depth, temperature and salinity distribution of catches	14
2.4.7 Density-dependent habitat selection	14
3 References	15

ABSTRACT

Ricard, D. and Gomez, C. 2021. Marine Fish and Invertebrate Atlas: Summarizing Geographic Distribution, Population Indices and Environmental Preferences in the Scotian Shelf and Bay of Fundy (1970-2020). Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 17 p.

The summer groundfish research vessel survey on the Scotian Shelf and in the Bay of Fundy started in 1970 and was designed to measure the distribution and abundance of major commercial fish species. Over time, additional information on non-commercial species was collected, and allowed considerable insight into ecosystem function and structure, as documented in many primary publications whose analyses used the survey data. The same groundfish survey database has also been used to produce species status reports, atlases of species distribution and remains an essential source of information for stock assessments in the Maritimes Region of Fisheries and Oceans Canada. This report builds on previous work and former atlases by updating a comprehensive suite of indices to assess population status and environmental preferences of 104 species. For each species, trends in geographic distribution and biomass or abundance were plotted. The spatial extent of distribution was plotted over time to gauge how the area occupied has changed. The relationship between abundance or biomass and spatial extent reflected whether the species distribution expands when abundance or biomass increases. Length frequencies over time depicted any changes in mean size. The plots of condition over time revealed whether individual fish are fatter or thinner than their long term mean. Depth, temperature and salinity preferences were estimated to gauge the range of suitable environmental parameters for each species. Finally, for each stratum, the slope describing how local density varies with regional abundance was estimated.

RÉSUMÉ

Ricard, D. and Gomez, C. 2021. Marine Fish and Invertebrate Atlas: Summarizing Geographic Distribution, Population Indices and Environmental Preferences in the Scotian Shelf and Bay of Fundy (1970-2020). Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 17 p.

Voici le résumé. Lorem ipsum dolor sit amet, consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua. Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat. Duis aute irure dolor in reprehenderit in voluptate velit esse cillum dolore eu fugiat nulla pariatur. Excepteur sint occaecat cupidatat non proident, sunt in culpa qui officia deserunt mollit anim id est laborum.

1 Introduction

The summer (July-August) groundfish research vessel survey on the Scotian Shelf and in the Bay of Fundy was started in 1970 by Fisheries and Oceans Canada Maritimes Region. The survey was originally designed to measure the distribution and abundance of major commercial fish species. Over time, information on non-commercial species was also collected. The groundfish survey database storing the information collected during the annual survey provides the main source of fisheries-independent information for marine species in the region. This information is routinely used to support stock assessments, to produce species status reports and has been previously used to publish atlases of species distribution.

The current document is an update of an earlier report (Ricard and Shackell 2013) that built on former atlases by updating a comprehensive suite of derived indices for 104 species to assess population status and environmental preferences. The information collected during the survey is stored in a relational database management system archived at Fisheries and Oceans Canada Maritimes Region which contains detailed information about the sampling locations and the associated catch. Tow-level survey data is also publicly available from the Ocean Biogeographic Information System (DFO 2016) and (FGP link TBA). The present atlas follows on the work done by Fisheries and Oceans colleagues from the northern Gulf of St. Lawrence (Bourdages and Ouellet 2012), southern Gulf of St. Lawrence (Benoît et al. 2003) and on earlier work in the Scotian Shelf (Simon and Comeau 1994; Horsman and Shackell 2009).

To facilitate updates and foster collaboration on the analyses of the survey data, the computer code necessary to extract the data, to perform the analyses presented herein, and to reproduce and update the current document is made available in a git repository (Ricard and Gomez 2021).

The survey area covers three major Northwest Atlantic Fisheries Organization (NAFO) zones that divide the shelf into the colder east 4V and 4W (strata 440-466) and warmer west 4X (strata 470-495). Temporal trends are plotted by NAFO regions for several species. For each species, trends in geographic distribution and biomass or abundance are plotted. Some caution is required in interpreting the results obtained for several taxa due to low sample size as explained later in the text. The spatial extent of distribution is plotted over time to gauge how the area occupied has changed. The relationship between biomass and spatial extent reflects whether the species distribution expands when biomass increases. For each strata, the slope describing how local density varies with regional abundance was estimated (Myers and Stokes 1989). These slopes were then plotted against a habitat suitability index to identify important strata for each species. Then, length frequencies over time depicted any changes in mean size. The plots of condition over time revealed whether individual fish are fatter or thinner than their long term mean. Finally, depth, temperature and salinity preferences were estimated to gauge the range of environmental parameters (Perry and Smith 1994). A full ecological interpretation of trends is beyond the scope of this report. Other documents stemming from peer-reviewed scientific processes under the auspices of the [Canadian Science Advisory Secretariat](#) (CSAS) provide further descriptions of spatio-temporal trends in different indicators and put the information collected during the summer groundfish research vessel survey in a more focused context (see for example Clark and Emberley (2011)).

2 Methods

2.1 Survey Description

The survey is conducted annually in July-August and covers the Scotian Shelf and the Bay of Fundy (Figure 1). It normally involves two separate two-week trips on board an offshore fisheries vessel from the Canadian Coast Guard.

A number of changes in fishing gear type and vessels used occurred since the onset of sampling activities (Clark and Emberley 2011).

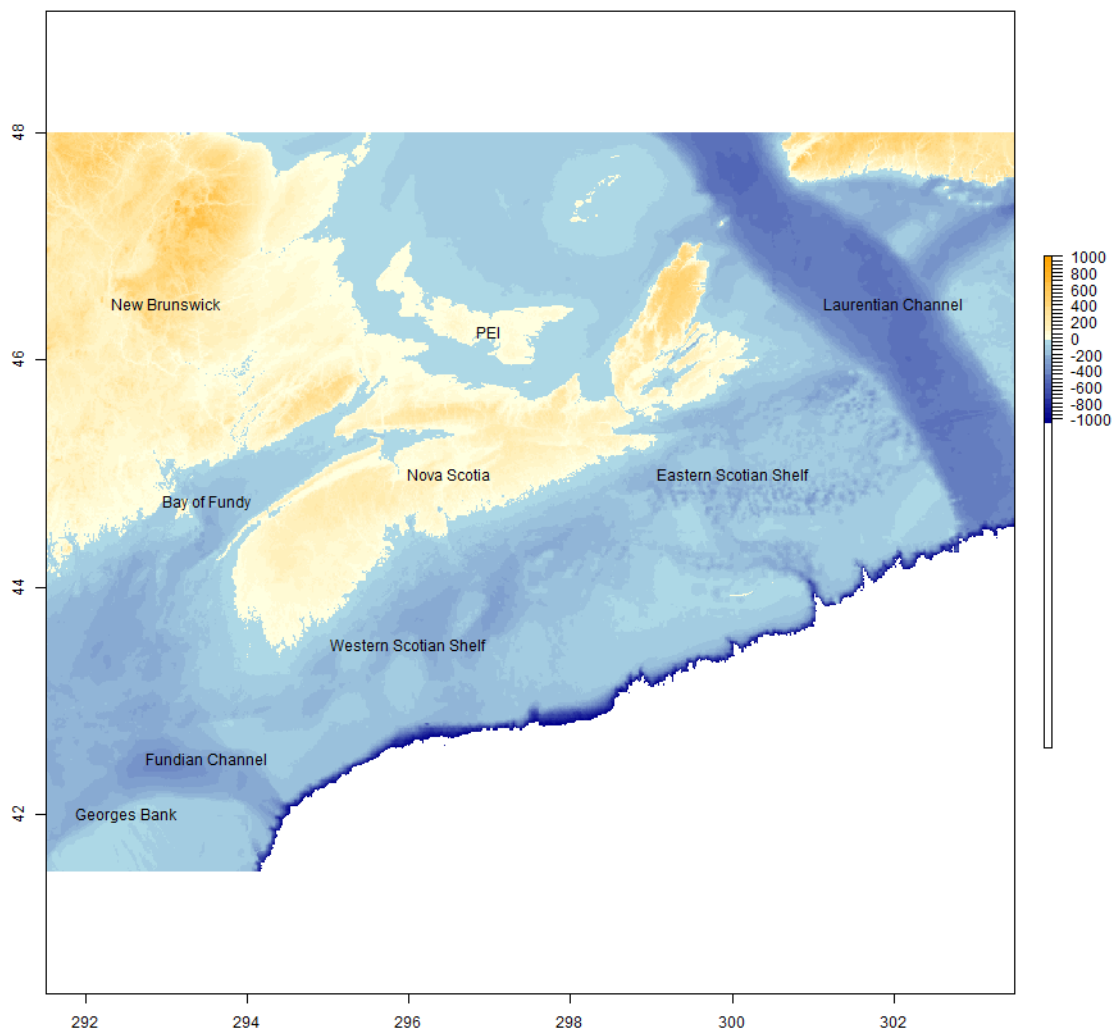


Figure 1. Map of the Scotian Shelf and Bay of Fundy.

2.2 Sampling Design

The summer survey covers divisions 4V, 4W and 4X of the Northwest Atlantic Fisheries Organization (NAFO) which includes the Scotian Shelf and the Bay of Fundy. The eastern limit of the survey is the Laurentian Channel and the western limit is the Fundian Channel (Figure 1).

The survey follows a stratified random design (Doubleday and Rivard 1981; Lohr 1999) (Figure 2). The number of tows conducted in each stratum is approximately proportional to its surface area.

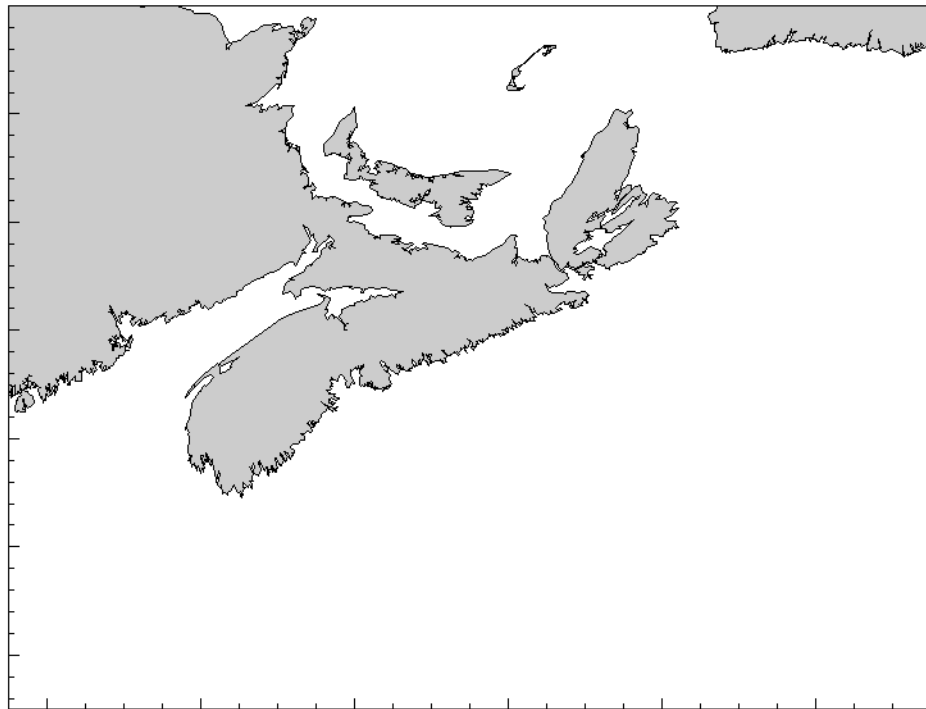


Figure 2. Map of the Summer survey strata.

The basic sampling unit of the survey is a 30-minute fishing tow conducted at a speed of 3.5 knots. This yields a distance towed of 1.75 nautical miles.

After each tow the catch is sorted by species and weighed. Each fish caught is then measured, and further sampling of individual fish weight, maturity status and age are performed for different length classes. When catches exceed 300 individuals, a random sub-sample is used to obtain the length and weight measurements.

The location of representative tows appears in Figure 3.

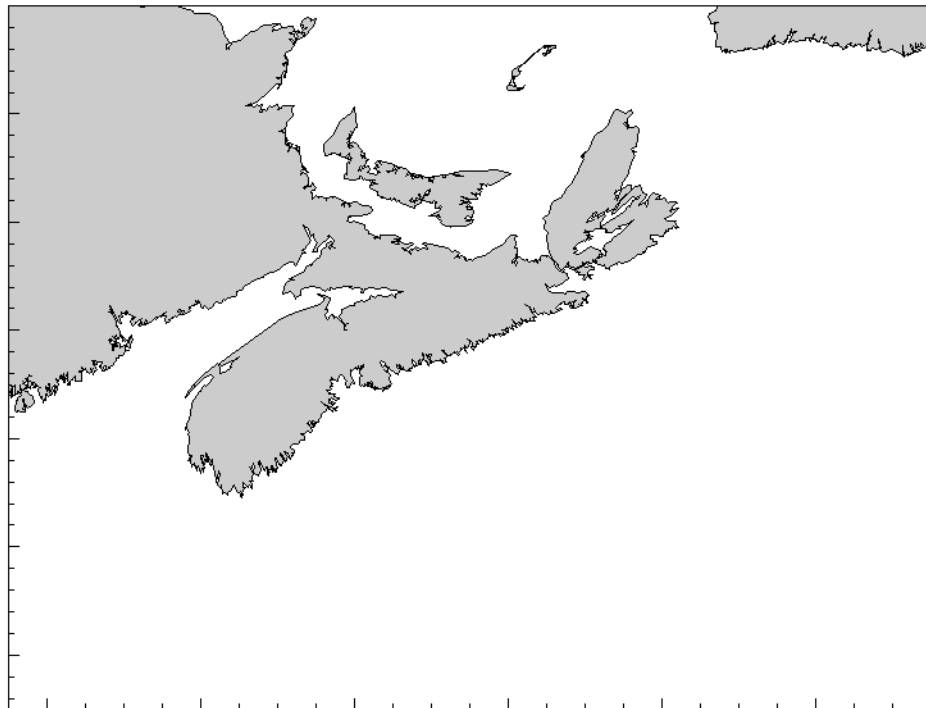


Figure 3. Map of the Summer survey tows.

2.3 Taxonomic Levels

Fish species caught during the surveys are identified by trained scientific personnel and their scientific name is determined. An internal species code used in the relational database is reported for each species (Losier and Waite 1989).

By its nature as a bottom trawl, the fishing gear used in the survey catches certain species better than others. To ensure that meaningful ecological information can be extracted from catch samples, we report the catch records for the subset of species that are caught reliably by the gear. To appear in this atlas, a species must have had a minimum of 10 observations over the duration of the survey activities. While both catch abundance and weight are recorded, the weight of species that appear at low abundances is often recorded as zero in the earlier parts of the survey when scales of appropriate precision were not available.

We divided the species caught into five categories based on 1) their taxonomic classification, 2) the number of recorded observations, and 3) their period of valid identification (Table 1). Category "LF", for "long frequent", was assigned to species that have more than 1000 records since 1970 and have been consistently identified since the onset of the survey. Category "LI", for "long intermediate", was assigned to species that had between 1000 and 200 catch records. Rare and elusive species (those with less than 200 catch records over the duration of the survey) are also reported but to a lower level of analytical details (Category "LR", for "long rare"). Category "SF", for "short frequent", was assigned to invertebrate species that were consistently sampled only since 1999 (Tremblay M. J. 2007). And category "SR", for "short rare" for invertebrate species consistently sampled only since 1999 and with less than 200 catch records. The list of taxa covered in this document is presented in phylogenetic order (Nelson J. S. et al. 2004) in Table 2. To ensure concordance with authoritative taxonomic information, the AphiaID from the World Register of Marine Species is also provided in Table 2 (Appeltans et al. 2012).

Category	Name	Description
L	long	consistently identified since the onset of the survey in 1970
LF	long frequent	species that have more than 1000 catch records
LI	long intermediate	species that had between 1000 and 200 catch records
LR	long rare	species with less than 200 catch records
S	short	invertebrate species that were consistently sampled only since 1999
SF	short frequent	species with more than 200 catch records
SR	short rare	species with less than 200 catch records

Table 1. Taxonomic levels

Table 2. List of species included in the Atlas. The species reported here are listed in phylogenetic order as per Page L. M. et al. (2013). For each taxonomic order and class, each species is listed in the table, its taxonomic family and scientific name is provided, along with its French and English common names, the species code used in the survey database, its AphiaID and a link to the World Registry of Marine Species, its number of catch records in the survey database and its classification category as defined in section 2.3.

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
Myxini							
<i>Myxiniiformes</i>							
Myxinidae	<i>Myxine glutinosa</i>	Atlantic hagfish	Myxine du nord	241	101170	804	I
Petromyzonti							
<i>Petromyzontiiformes</i>							
Petromyzontidae	<i>Petromyzon marinus</i>	Sea lamprey	Lamproie marine	240	101174	16	LR
Actinopterygii							
<i>Gadiiformes</i>							
Gadidae	<i>Gadus morhua</i>	Atlantic cod	Morue franche	10	126436	5451	L
	<i>Melanogrammus aeglefinus</i>	Haddock	Aiglefin	11	126437	5827	L
Phycidae	<i>Urophycis tenuis</i>	White hake	Merluche blanche	12	126504	3524	L
	<i>Urophycis chuss</i>	Red hake	Merluche écureuil	13	126503	2195	L
Merlucciidae	<i>Merluccius bilinearis</i>	Silver hake	Merlu argenté	14	158962	4936	L
Lotidae	<i>Brosme brosme</i>	Cusk	Brosme	15	126447	688	I
Gadidae	<i>Pollachius virens</i>	Pollock	Goberge	16	126441	2787	L
	<i>Microgadus tomcod</i>	Atlantic tomcod	Poulamon atlantique	17	158928	44	LR
Merlucciidae	<i>Merluccius albidus</i>	Offshore silver hake	Merlu argenté du large	19	158748	161	LR
<i>Scorpaeniformes</i>							
Sebastidae	<i>Sebastes</i>	Atlantic redfishes	Sébastes de l'Atlantique	23	126175	4152	L
<i>Pleuronectiformes</i>							
Pleuronectidae	<i>Hippoglossus hippoglossus</i>	Atlantic halibut	Flétan de l'Atlantique	30	127138	1634	L

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
	<i>Reinhardtius hippoglossoides</i>	Greenland halibut	Flétan noir	31	127144	736	I
	<i>Hippoglossoides platessoides</i>	American plaice	Plie canadienne	40	127137	6023	L
	<i>Glyptocephalus cynoglossus</i>	Witch flounder	Plie grise	41	127136	4301	L
	<i>Limanda ferruginea</i>	Yellowtail flounder	Limande à queue jaune	42	158879	3233	L
	<i>Pseudopleuronectes americanus</i>	Winter flounder	Limande-plie rouge	43	158885	1632	L
Paralichthyidae	<i>Citharichthys arcifrons</i>	Gulf Stream flounder	Plie du Gulf Stream	44	158791	382	I
<i>Perciformes</i>							
Anarhichadidae	<i>Anarhichas lupus</i>	Atlantic wolffish	Loup atlantique	50	126758	1572	L
	<i>Anarhichas minor</i>	Spotted wolffish	Loup tacheté	51	126759	20	LR
	<i>Anarhichas denticulatus</i>	Northern wolffish	Loup à tête large	52	126757	17	LR
<i>Clupeiformes</i>							
Clupeidae	<i>Clupea harengus</i>	Atlantic herring	Hareng de l'Atlantique	60	126417	3487	L
	<i>Alosa sapidissima</i>	American shad	Alose savoureuse	61	158670	468	I
	<i>Alosa pseudoharengus</i>	Alewife	Gaspereau	62	158669	977	I
<i>Osmeriformes</i>							
Osmeridae	<i>Osmerus mordax</i>	Rainbow smelt	Éperlan arc-en-ciel	63	126737	59	LR
	<i>Mallotus villosus</i>	Capelin	Capelan	64	126735	540	I
<i>Perciformes</i>							
Scombridae	<i>Scomber scombrus</i>	Atlantic mackerel	Maquereau commun	70	127023	696	I
<i>Gadiformes</i>							

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
Phycidae	<i>Phycis chesteri</i>	Longfin hake	Merluche à longues nageoires	112	158988	784	I
Lotidae	<i>Enchelyopus cimbrius</i>	Fourbeard rockling	Motelle à quatre barbillons	114	126450	693	I
<i>Perciformes</i>							
Labridae	<i>Tautoglabrus adspersus</i>	Cunner	Tanche-tautogue	122	159785	82	LR
<i>Scorpaeniformes</i>							
Sebastidae	<i>Helicolenus dactylopterus</i>	Blackbelly rosefish	Sébaste chèvre	123	127251	610	I
<i>Pleuronectiformes</i>							
Paralichthyidae	<i>Hippoglossina oblonga</i>	Fourspot flounder	Cardeau à quatre ocelles	142	158833	76	LR
Scophthalmidae	<i>Scophthalmus aquosus</i>	Windowpane flounder	Turbot de sable	143	158907	115	LR
<i>Aulopiformes</i>							
Chlorophthalmidae	<i>Parasudis truculenta</i>	Longnose greeneye	Oeil-vert à long nez	149	158868	45	LR
<i>Myctophiformes</i>							
Myctophidae	<i>Myctophidae</i>	Lanternfishes	Poissons-lanternes	150	125498	160	LR
<i>Aulopiformes</i>							
Chlorophthalmidae	<i>Chlorophthalmus agassizi</i>	Shortnose greeneye	Éperlan du large	156	126336	78	LR
<i>Stomiiformes</i>							
Sternoptychidae	<i>Mauroliscus muelleri</i>	Silvery lightfish	Brossé améthyste	158	127312	52	LR
Stomiidae	<i>Stomias boa</i>	Boa dragonfish	Dragon-boa	159	127374	20	LR
<i>Argentiniformes</i>							
Argentinidae	<i>Argentina silus</i>	Greater argentine	Grande argentine	160	126715	963	I
<i>Scorpaeniformes</i>							
Cottidae	<i>Myoxocephalus octodecemspinosus</i>	Longhorn sculpin	Chaboisseau à dix-huit épines	300	159520	3292	L

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
	<i>Myoxocephalus scorpius</i>	Shorthorn sculpin	Chaboisseau à épines courtes	301	127203	131	LR
	<i>Myoxocephalus aeneus</i>	Grubby	Chaboisseau bronzé	303	159519	40	LR
	<i>Triglops murrayi</i>	Moustache sculpin	Faux-trigle armé	304	127205	1182	L
	<i>Artediiellus uncinatus</i>	Arctic hookear sculpin	Hameçon neigeux	306	127195	306	I
Psychrolutidae	<i>Cottunculus microps</i>	Polar sculpin	Cotte polaire	307	127235	29	LR
Cottidae	<i>Icelus spatula</i>	Spatulate sculpin	Icèle spatulée	314	127200	40	LR
Hemitriptoridae	<i>Hemitripterus americanus</i>	Sea raven	Hémitriptère atlantique	320	159518	2126	L
Agonidae	<i>Aspidophoroides monopterygius</i>	Alligatorfish	Poisson-alligator atlantique	340	159459	1029	L
	<i>Ulcina olrikii</i>	Arctic alligatorfish	Poisson-alligator arctique	341	274356	13	LR
	<i>Leptagonus decagonus</i>	Atlantic poacher	Agone atlantique	350	127191	266	I
	<i>Agonidae</i>	Alligatorfishes	Poissons-alligator	351	125588	43	LR
<i>Lophiiformes</i>	<i>Lophius americanus</i>	Monkfish	Baudroie d'Amérique	400	159184	1970	L
<i>Gadiformes</i>	<i>Nezumia bairdii</i>	Marlin-spike grenadier	Grenadier du Grand Banc	410	183289	529	I
	<i>Trachyrincus murrayi</i>	Roughnose grenadier	Grenadier-scie	412	126481	18	LR
	<i>Coryphaenoides rupestris</i>	Roundnose grenadier	Grenadier de roche	414	158960	17	LR
<i>Scorpaeniformes</i>	<i>Cyclopterus lumpus</i>	Lumpfish	Lompe	501	127214	216	I

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
Liparidae	<i>Eumicrotremus spinosus</i>	Atlantic spiny lumpsucker	Petite poule de mer atlantique	502	127217	226	I
	<i>Liparis atlanticus</i>	Atlantic seasnail	Limace atlantique	503	159524	34	LR
	<i>Liparis fabricii</i>	Gelatinous snailfish	Limace gélatineuse	505	127218	27	LR
	<i>Liparis gibbus</i>	Variegated snailfish	Limace marbée	512	159526	41	LR
	<i>Careproctus reinhardtii</i>	Sea tadpole	Petite limace de mer	520	127212	18	LR
<i>Perciformes</i>							
Zoarcidae	<i>Lycenchelys verrillii</i>	Wolf eelpout	Lycode à tête longue	603	159258	40	LR
<i>Anguilliformes</i>							
Nemichthyidae	<i>Nemichthys scolopaceus</i>	Slender snipe eel	Avocette ruban	604	126306	28	LR
<i>Perciformes</i>							
Ammodytidae	<i>Ammodytes dubius</i>	Sand lance	Langon	610	151520	1283	I
Zoarcidae	<i>Lycodes terraenovae</i>	Newfoundland eelpout	Lycode du Labrador	619	127117	64	LR
	<i>Lycodes lavalaei</i>	Newfoundland eelpout	Lycode du Labrador	620	127107	72	LR
Pholidae	<i>Pholis gunnellus</i>	Rock gunnel	Sigouine de roche	621	126996	21	LR
Stichaeidae	<i>Lumpenus lampretaeformis</i>	Snakeblenny	Lompénie-serpent	622	154675	423	I
	<i>Leptoclinus maculatus</i>	Daubed shanny	Lompénie tachetée	623	127072	443	I
	<i>Ulvaria subbifurcata</i>	Radiated shanny	Ulvaire deux-lignes	625	159821	145	LR
	<i>Eumesogrammus praecius</i>	Fourline snakeblenny	Quatre-lignes atlantique	626	159817	40	LR
Cryptacanthodidae	<i>Cryptacanthodes maculatus</i>	Wrymouth	Terrassier tacheté	630	159675	120	LR
Callionymidae	<i>Foetorepus agassizii</i>	Spotfin dragonet	Dragonnnet tacheté	637	276339	20	LR

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
Zoarcidae	<i>Zoarces americanus</i>	Ocean pout	Loquette d'Amérique	640	159267	1478	L
	<i>Lycodes reticulatus</i>	Arctic eelpout	Lycode arctique	641	127112	70	LR
	<i>Melanostigma atlanticum</i>	Atlantic soft pout	Molasse atlantique	646	127120	43	LR
Stromateidae	<i>Lycodes vahlii</i>	Vahl's eelpout	Lycode à carreaux	647	127118	565	I
	<i>Peprilus triacanthus</i>	Atlantic butterflyfish	Stromaté fossette	701	159828	487	I
Zeiformes	<i>Zenopsis conchifer</i>	Silvery John dory	Saint Pierre argenté	704	127426	39	LR
Aulopiformes	<i>Arctozenus risso</i>	White barracudina	Lussion blanc	712	126352	196	LR
Belontiiformes	<i>Scomberesox saurus</i>	Atlantic saury	Balaou atlantique	720	126392	37	LR
Stomiiformes	<i>Sternoptychidae</i>	Hatchetfishes	Haches d'argent	741	125603	21	LR
Lophiiformes	<i>Dibranchus atlanticus</i>	Atlantic batfish	Mathe atlantique	742	126558	18	LR
Pleuronectiformes	<i>Symphurus diomedeanus</i>	Spottedfin tonguefish	Langue fil noir	816	159358	24	LR
Scorpaeniformes	<i>Artediiellus atlanticus</i>	Atlantic hookear sculpin	Hameçon atlantique	880	127193	258	I
Elasmobranchii							
Rajiformes							
Rajidae	<i>Dipturus laevis</i>	Barndoor skate	Grande raie	200	158548	246	I
	<i>Amblyraja radiata</i>	Thorny skate	Raie épineuse	201	105865	3937	L
	<i>Malacoraja senta</i>	Smooth skate	Raie lisse	202	158554	1773	L

Family	Scientific name	English name	French name	Species code	AphiaID	Num. records	Category
	<i>Leucoraja erinacea</i>	Little skate	Raie hérisson	203	158551	712	I
	<i>Leucoraja ocellata</i>	Winter skate	Raie tachetée	204	158553	1180	L
<i>Squaliformes</i>							
Squalidae	<i>Squalus acanthias</i>	Picked dogfish	Aiguillat commun	220	105923	1985	L
Etmopteridae	<i>Centroscyllium fabricii</i>	Black dogfish	Aiguillat noir	221	105906	31	LR
Cephalopoda							
Oegopsida							
Ommastrephidae	<i>Illex illecebrosus</i>	Northern shortfin squid	Encornet rouge nordique	4511	153087	4836	L
<i>Myopsida</i>							
Loliginidae	<i>Doryteuthis pealeii</i>	Longfin inshore squid	Calmar totam	4512	574541	96	LR
Malacostraca							
<i>Decapoda</i>							
Pandalidae	<i>Pandalus borealis</i>	Northern prawn	Crevette nordique	2211	107649	718	S
Cancridae	<i>Cancer borealis</i>	Jonah crab	Tourteau jona	2511	158056	1387	S
	<i>Cancer irroratus</i>	Atlantic rock crab	Tourteau poinçolos	2513	158057	788	S
Oregoniidae	<i>Hyas coarctatus</i>	Arctic lyre crab	Crabe Hyas coarctatus	2521	107323	711	S
Lithodidae	<i>Lithodes maja</i>	Atlantic king crab	Crabe épineux du nord	2523	107205	531	S
Oregoniidae	<i>Chionoecetes opilio</i>	Queen crab	Crabe des neiges	2526	107315	1546	S
Geryonidae	<i>Hyas araneus</i>	Great spider crab	Crabe lyre araignée	2527	107322	625	S
	<i>Chaceon quinquedens</i>	Red deepsea crab	Crabe rouge	2532	158407	33	SR
Nephropidae	<i>Homarus americanus</i>	American lobster	Homard américain	2550	156134	1623	S

2.4 Analyses

The Oracle relational database where all data are stored was accessible from the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. Structured Query Language (SQL) is used to extract the data from the production server and to create the data products used in all subsequent analyses. Catch records classified as "valid" (i.e. a representative tow without damage to the net) are used in the current analyses. To make the available samples comparable, catch number and weight for each species was standardized for the distance towed.

All data processing and analyses were conducted using the R software (R Core Team 2020) using packages gstat (Pebesma 2004), PBSmapping (Schnute et al. 2019), RODBC (Ripley and Lapsley 2019), spatstat (Baddeley 2015), maptools (Bivand and Lewin-Koh 2020), rgeos (Bivand and Rundel 2020), classInt(Bivand 2020), RColorBrewer(Neuwirth 2014), MASS (Ripley et al. 2020), worms (Holstein 2018), and tidyverse (Wickham 2019). The present document is rendered as a Technical Report using the csasdown R package developed and maintained by Fisheries and Oceans Canada scientists (Anderson et al. In press).

2.4.1 Geographic distribution of catches

Spatial interpolation of catch biomass (kg/tow) or abundance (number/tow) was done using a weighting inversely proportional to the distance, using function "idw" of the spatstat R package (Baddeley 2015).

2.4.2 Abundance and biomass indices

For each species, stratified random estimates of catch abundance and biomass (Smith 1996) were computed for each year. Yearly estimates of the standard error were also computed.

2.4.3 Distribution indices

For each Category L, I and S fish species, the minimum area required to account for 75% and 95% of the total biomass or abundance were computed (D75% and D95%). These measures of distributions were computed for each year by using the Lorenz curve of mean stratum-level catch estimates and the area of occupied strata (Swain and Sinclair 1994; Swain and Morin 1996).

2.4.4 Length frequencies

The length frequency distribution of catch is tabulated for each seven-year period (1970-2009), and last ten-year period (2010-2020).

2.4.5 Length-weight relationship and condition factor

The relationship between the weight and the length of fish was estimated using the following non-linear isometric relationship:

$$W = \alpha L^\beta$$

where W is the total weight (g), L is the length (cm), and, α and β are the parameters to be estimated.

Average fish condition (C) was computed as:

$$C = \frac{W}{\alpha L^\beta}$$

2.4.6 Depth, temperature and salinity distribution of catches

For each category L species, We followed the methods developed by (Perry and Smith 1994) and generated cumulative frequency distributions of depth, temperature and salinity of survey catches.

2.4.7 Density-dependent habitat selection

We followed the methods of (Myers and Stokes 1989) to evaluate how fish abundance in each stratum varied with overall temporal fluctuations of population abundance.

For each category L species, we fitted a model of the relationship between stratum-level density and overall abundance (the yearly stratified random estimate of abundance, defined above). To properly use the observations of zero catch while accounting for the logarithmic distribution of catch abundance, we implemented the model as a generalised linear using a log link and a Poisson error distribution:

$$Y_{h,i} = \alpha_h Y_i^{\beta_h}$$

where, $y_{h,i}$ is the average abundance of stratum h in year i , and $\alpha_{h,i}$ and $\beta_{h,i}$ are the fitted parameters. The estimated parameter $\beta_{h,i}$ is referred to as the “slope parameter” and indicates whether stratum-level density is positively ($\beta_{h,i} \leq 0$), negatively ($\beta_{h,i} \geq 0$) or negligibly ($\beta_{h,i} \approx 0$) related to population abundance.

To estimate the suitability of each stratum, the median abundance observed during the years that are in the top 25% of yearly estimates is used. We combine the slope parameter estimates from the above model with the median abundance to identify strata that have consistently high abundance and whose local density is weakly related to fluctuation in population abundance ($\beta_{h,i} \approx 0$). Preferred strata are identified for each category L species.

3 References

- Anderson, S.C., Grandin, C., Edwards, A.M., Grinnell, M.H., Ricard, D., and Haigh, R. (In press). Csasdown: Reproducible CSAS Reports with Bookdown.
- Appeltans, W., Bouchet, P., Boxshall, G.A., De Broyer, C., Voogd, N.J. de, Gordon, D.P., Hoeksema, B.W., Horton, T., Kennedy, M., J., M., Poore, G.C.B., Read, G., Stöhr, S., Walter, T.C., and Costello, M.J. (*Editors*). 2012. World register of marine species. Accessed at <http://www.marinespecies.org> on 2020-12-1.
- Baddeley, R., A. 2015. Spatial point patterns: Methodology and applications with R. Chapman; Hall/CRC Press, London <http://www.crcpress.com/Spatial-Point-Patterns-Methodology-and-Applications-with-R/Baddeley-Rubak-Turner/9781482210200/>.
- Benoît, H.P., Abgrall, M.-J., and Swain, D.P. 2003. [An assessment of the general status of marine and diadromous fish species in the southern Gulf of St. Lawrence based on annual bottom trawl surveys \(1971-2002\)](#). Can. Tech. Rep. Fish. Aquat. Sci. 2472: iv + 183 p.
- Bivand, R. 2020. ClassInt: Choose univariate class intervals. R package version 0.4-3 <https://CRAN.R-project.org/package=classInt>.
- Bivand, R., and Lewin-Koh, N. 2020. Maptools: Tools for handling spatial objects. R package version 1.0-2 <https://CRAN.R-project.org/package=maptools>.
- Bivand, R., and Rundel, C. 2020. Rgeos: Interface to geometry engine - open source ('geos'). R package version 0.5-5 <http://CRAN.R-project.org/package=rgeos>.
- Bourdages, H., and Ouellet, J.-F. 2012. [Geographic distribution and abundance indices of marine fish in the northern Gulf of St. Lawrence \(1990-2009\)](#). Can. Tech. Rep. Fish. Aquat. Sci. 2963: vi + 171 p.
- Clark, D.W., and Emberley, J. 2011. Update of the 2010 summer scotian shelf and bay of fundy research vessel survey. Can. Tech. Rep. Fish. Aquat. Sci.: 1238: ix + 98 p.
- DFO. 2016. DFO maritimes research vessel trawl surveys invertebrate observations. Version 7 in obis canada digital collections. Bedford Institute of Oceanography, Dartmouth, NS, Canada, Published by OBIS, Digital 2016.
- Doubleday, W.G., and Rivard, D. 1981. Bottom trawl surveys. Can. Spec. Publ. Fish. Aquat. Sci: 58: 237 pp.
- Holstein, J. 2018. Worms: Retriving aphia information from world register of marine species. R package version 0.2.2 <https://CRAN.R-project.org/package=worms>.
- Horsman, T.L., and Shackell, N.L. 2009. [Atlas of important habitat for key fish species of the Scotian Shelf, Canada](#). Can. Tech. Rep. Fish. Aquat. Sci. 2835: viii + 82 p.
- Lohr, S. 1999. Sampling: Design and analysis. Pacific Grove, CA: Brooks/Cole Publishing Company.
- Losier, R.J., and Waite, L.E. 1989. Systematic listing of scientific and/or common names of invertebrates and marine plants and their respective codes used by marine fish division,

- Fisheries and Oceans, Scotia-Fundy Region. Canadian Data Report of Fisheries and Aquatic Sciences (721).
- Myers, R.A., and Stokes, K. 1989. Density-dependent habitat utilization of groundfish and the improvement of research surveys. (D:15). International Council for the Exploration of the Sea Council Meeting.
- Nelson J. S., Crossman E. J., Espinosa-Perez H., Findley L. T., Gilbert C. R., Lea R. N., and D., W.J. 2004. Common and scientific names of fishes from the united states canada and mexico. Number 29 in Special Publication. American Fisheries Society, Bethesda, Maryland, sixth edition.
- Neuwirth, E. 2014. RColorBrewer:ColorBrewer palettes. R package version 1.1-2 <https://CRAN.R-project.org/package=RColorBrewer>.
- Page L. M., Espinosa-Pérez H., Findley L. T., Gilbert C. R., Lea R. N., Mandrak N. E., and M.R.L., and S., N.J. 2013. Common and scientific names of fishes from the United States, Canada, and Mexico. American Fisheries Society.
- Pebesma, E. 2004. Multivariable geostatistics in S: The gstat package. *In* Computers and Geosciences.
- Perry, R.I., and Smith, S.J. 1994. Identifying habitat associations of marine fishes using survey data: An application to the northwest atlantic. Canadian Journal of Fisheries and Aquatic Sciences (51(3)): 589–602.
- R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Ricard, D., and Gomez, C. 2021. Maritimes-summer-atlas. <https://github.com/dfo-gulf-science/Maritimes-SUMMER-Atlas>; GitHub.
- Ricard, D., and Shackell, N.L. 2013. [Population status \(abundance/biomass, geographic extent, body size and condition\), important habitat, depth, temperature and salinity of marine fish and invertebrates on the Scotian Shelf and Bay of Fundy \(1970-2012\)](#). Can. Tech. Rep. Fish. Aquat. Sci. 3012: viii + 180 p.
- Ripley, B., and Lapsley, M. 2019. RODBC: ODBC database access. R package version 1.3-16 <http://CRAN.R-project.org/package=RODBC>.
- Ripley, B., Venables, B., Bates, D., Hornik, K., Gebhardt, A., and Firth, D. 2020. Modern applied statistics with s. R package version 7.3-53 <https://cran.r-project.org/web/packages/MASS/index.html>.
- Schnute, J.T., Boers, N., and Haigh, R. 2019. PBSmapping: Mapping fisheries data and spatial analysis tools. R package version 2.72.1 <https://cran.r-project.org/web/packages/PBSmapping/index.html>.
- Simon, J.E., and Comeau, P.A. 1994. [Summer distribution and abundance trends of species caught on the Scotian Shelf from 1970-92, by the research vessel groundfish survey](#). Can. Tech. Rep. Fish. Aquat. Sci. 1953.
- Smith, S.J. 1996. Assessment of groundfish stocks based on bottom trawl survey results. NAFO

Scientific Council Studies 28: 25–53.

Swain, D.P., and Morin, R. 1996. Relationships between geographic distribution and abundance of American plaice (*Hippoglossoides platessoides*) in the southern Gulf of St. Lawrence. Canadian Journal of Fisheries and Aquatic Sciences 53(1): 106–119.

Swain, D.P., and Sinclair, A.F. 1994. Fish distribution and catchability: What is the appropriate measure of distribution? Canadian Journal of Fisheries and Aquatic Sciences 51(5): 1046–1054.

Tremblay M. J., B.R., Black G. A. P. 2007. The distribution of common decapod crustaceans and other invertebrates recorded in annual ecosystem surveys of the scotian shelf 1999-2006, by the research vessel groundfish survey. Can. Tech. Rep. Fish. Aquat. Sci. 74.

Wickham, H. 2019. Tidyverse: Easily install and load the 'tidyverse'. R package version 1.3.0
<https://cran.r-project.org/web/packages/tidyverse/index.html>.